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SECURITY CLASSIFICATION OF THIS PAGE

AD-A206 769

(3)

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS DTIC FILE COPY
2a. SECURITY CLASSIFICATION AUTHORITY 2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
4. PERFORMING ORGANIZATION REPORT NUMBER(S) Test Operations Procedure 2-1-005	5. MONITORING ORGANIZATION REPORT NUMBER(S) same as item 4
6a. NAME OF PERFORMING ORGANIZATION U.S. ARMY COMBAT SYSTEMS TEST ACTIVITY 6b. OFFICE SYMBOL (If applicable) STECS-DA-ID	7a. NAME OF MONITORING ORGANIZATION U.S. ARMY TEST & EVALUATION COMMAND
6c. ADDRESS (City, State, and ZIP Code) ABERDEEN PROVING GROUND, MARYLAND 21005-5059	7b. ADDRESS (City, State, and ZIP Code) ABERDEEN PROVING GROUND, MD 21005-5055
8a. NAME OF FUNDING / SPONSORING ORGANIZATION (same as item 7a) 8b. OFFICE SYMBOL (If applicable) AMSTE-TC-M	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) (same as item 7b)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO.: AMC-R PROJECT NO.: 310-6 TASK NO.: WORK UNIT ACCESSION NO.:

11. TITLE (Include Security Classification)

"AUTOMOTIVE FIELD TEST EQUIPMENT AND INSTRUMENTATION" (U)

12. PERSONAL AUTHOR(S)

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM ______ TO ______	1989 April 4	13

16. SUPPLEMENTARY NOTATION

Supersedes MTP-2-1-005 dtd 27 July 1970

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Automotive; Test equipment; Field test equipment; Instrumentation

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Describes basic equipment and instrumentation for automotive field testing and its applications in determining vehicle performance, shock and vibration characteristics, and interior/exterior steady state noise levels.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code) / 22c. OFFICE SYMBOL

DD Form 1473, JUN 86 — Previous editions are obsolete.

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U.S. ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

AMSTE-RP-702-101
*Test Operations Procedure (TOP) 2-1-005 — 4 April 1989
AD No.

AUTOMOTIVE FIELD TEST EQUIPMENT AND INSTRUMENTATION

1. SCOPE.

a. Vehicle design and improvements in design are evaluated through accurate, quantitative measurements of numerous performance and operational characteristics. With each added capability requirement, a military vehicle becomes more complex, and a greater variety of equipment is needed to support testing and evaluation. In planning tests to acquire field performance data, the testing activity must be familiar with the full range of resources available, including laboratory testing facilities (MTP 2-1-002[1**]), the array of equipment and instrumentation currently available, and the manner in which they are assembled and operated to produce the most meaningful information.

b. This TOP describes basic equipment and instrumentation for automotive field testing and its applications in determining vehicle performance, shock and vibration characteristics, and interior/exterior steady state noise levels.

Keywords: Test equipment; automotive test equipment; (KT)

c. Certain items are cited for data-readout purposes for application during vehicle steady state test operations. Corresponding instrumentation with recording capability is ordinarily available for use in variable state test operations.

d. Instrumentation for measuring radio interference is not covered in this TOP. Requirements for measuring electromagnetic interference and susceptibility of electronic communications equipment are covered in MIL-STDs 461[a], 462[b], and 463.[c]

*Supersedes MTP 2-1-005 dated 27 July 1970.

**Footnote numbers/letters correspond to those in Appendix A.

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2. EQUIPMENT FOR MEASURING VEHICLE AND COMPONENT PERFORMANCE.

2.1 Mobile Dynamometers and Load-absorption Trailers. A mobile dynamometer is essentially a mobile laboratory designed for the following:

a. House the instrumentation for measuring vehicle full-load performance parameters.

b. Act as an energy-absorption unit wherein a load can be applied to a test vehicle to maintain full-throttle operation during drawbar pull and full-load cooling tests (TOPs 2-2-604[2] and 2-2-607[3] and ITOP 2-2-619[4]).

c. Provide a controlled mover for testing the retarding capabilities of the vehicle as in braking, power train overrun, grade retarders, rolling resistance, etc. (TOP 2-2-605[5]).

NOTE: A number of mobile dynamometers and load-absorption trailers (which supplement the load-absorption capability of the dynamometers) suitable for testing vehicles over paved roadways are listed in Table 1, along with a dynamometer designed for off-highway testing on soft terrain.

TABLE 1. CAPACITIES OF MOBILE DYNAMOMETERS AND LOAD-ABSORPTION TRAILERS

Equipment	Absorption Capacity, kN (lb)	Capacity of Load Cells, kN (lb)	
		Front	Rear
M16 Dynamometer (fig.1)	245 (55,000)	600 (135,000)	44 (10,000)
M18 Dynamometer (fig. 2)	111 (25,000)	290 (65,000)	22 (5000)
M8 Dynamometer (fig. 3)	33 (7500)	44 (10,000)	11 (2500)
Load-absorption Trailer, Heavy	180 (40,000)	--	--
M11 Off-road Dynamometer (fig. 4)	200 (45,000)	*	*

*Off-road dynamometer presently does not contain any permanently mounted instrumentation.

2.2 Instrumentation Used in Field Performance Measurements. Table 2 lists typical instrumentation used in dynamometer testing for measuring drawbar pull, temperatures, engine speed, driving sprocket or wheel speed, road speed, fuel flow, and similar performance characteristics of vehicles.

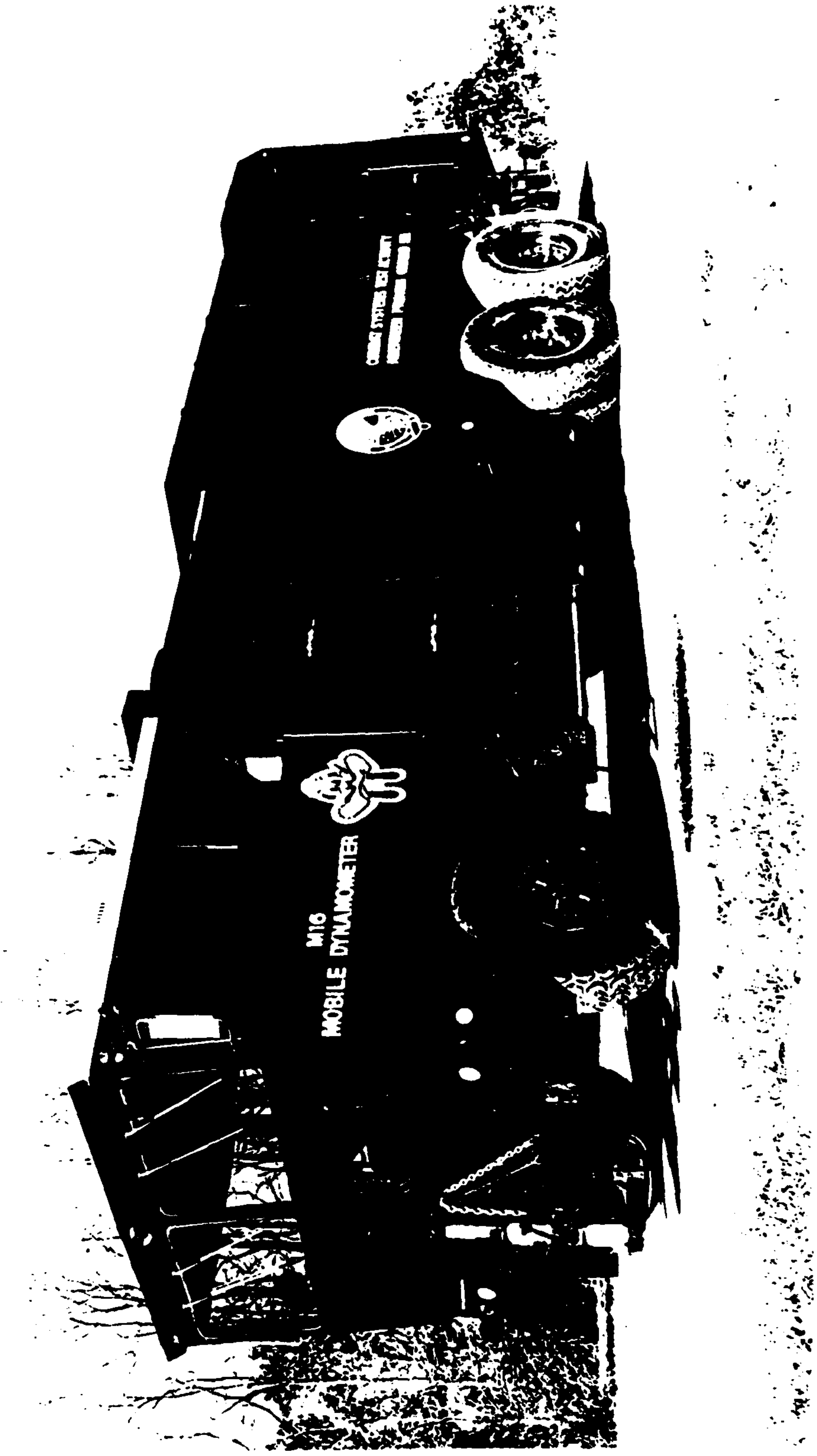

Figure 1. M16 Dynamometer.

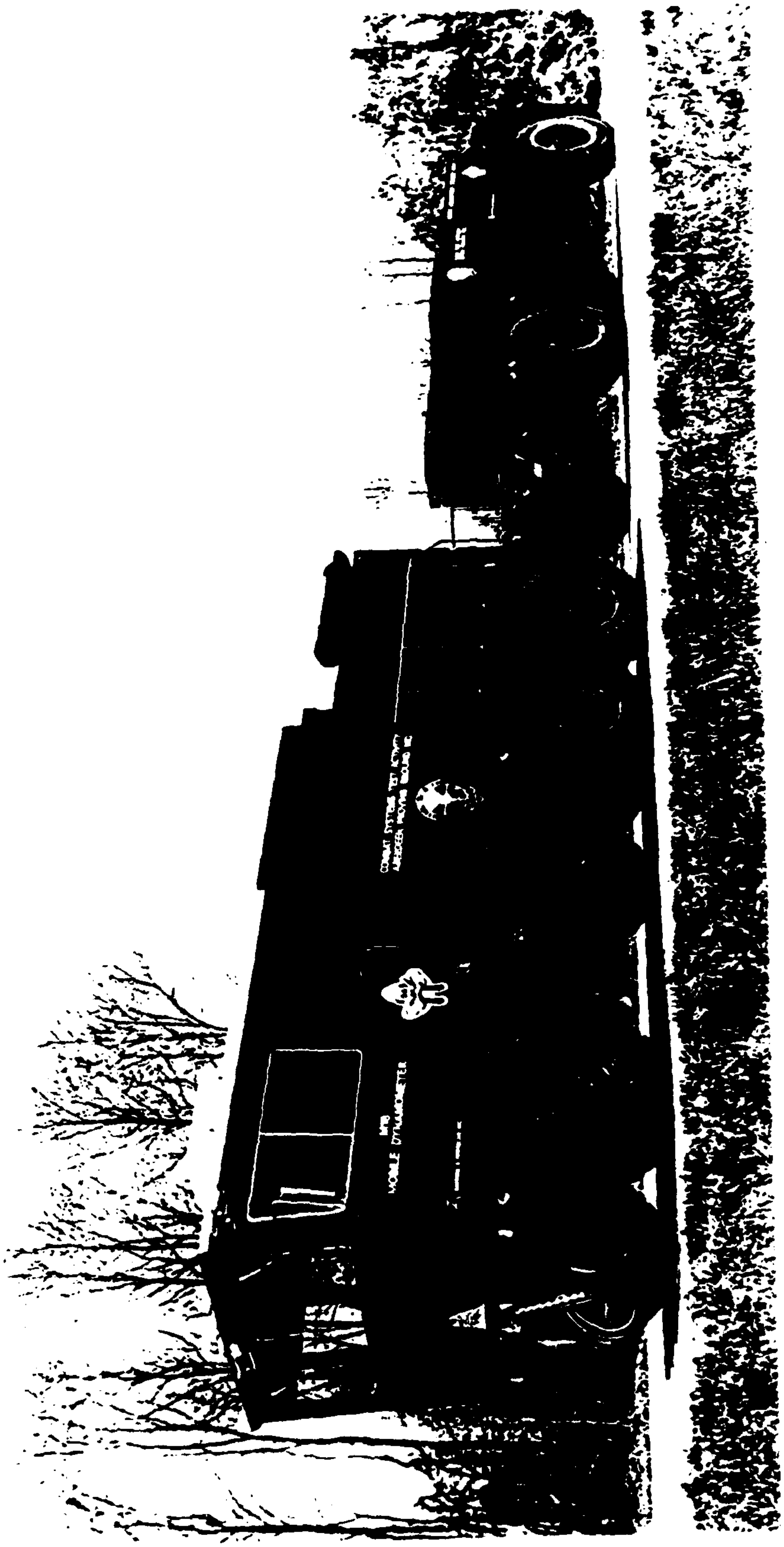

Figure 2. M18 Dynamometer with Load-Absorption Trailer.

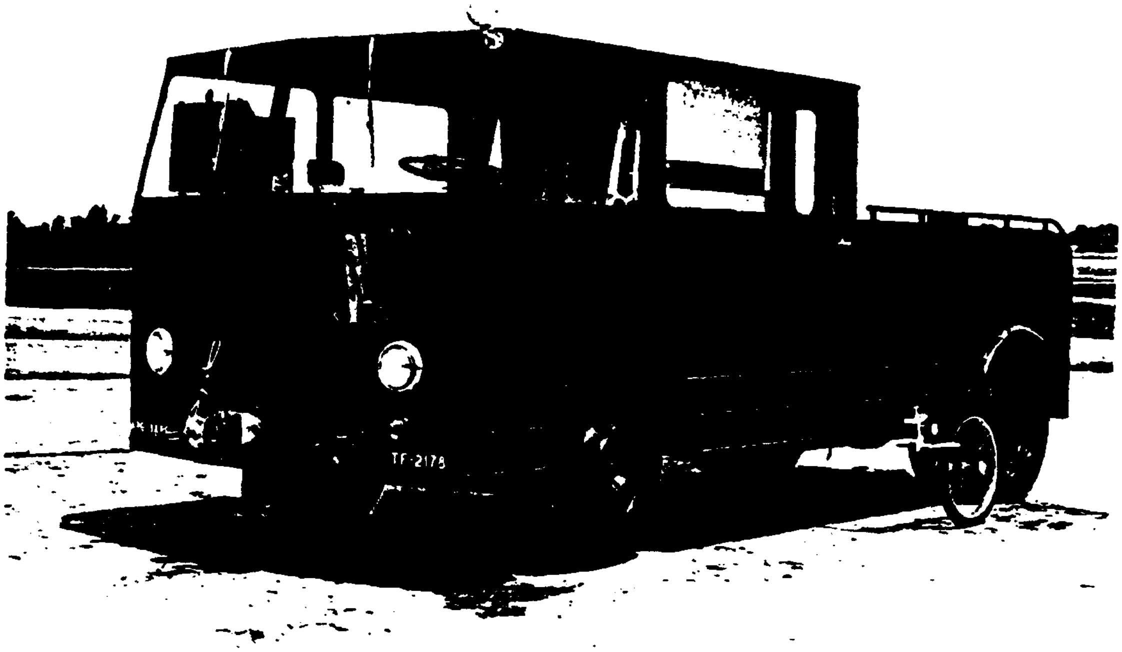

Figure 3. M8 Dynamometer.

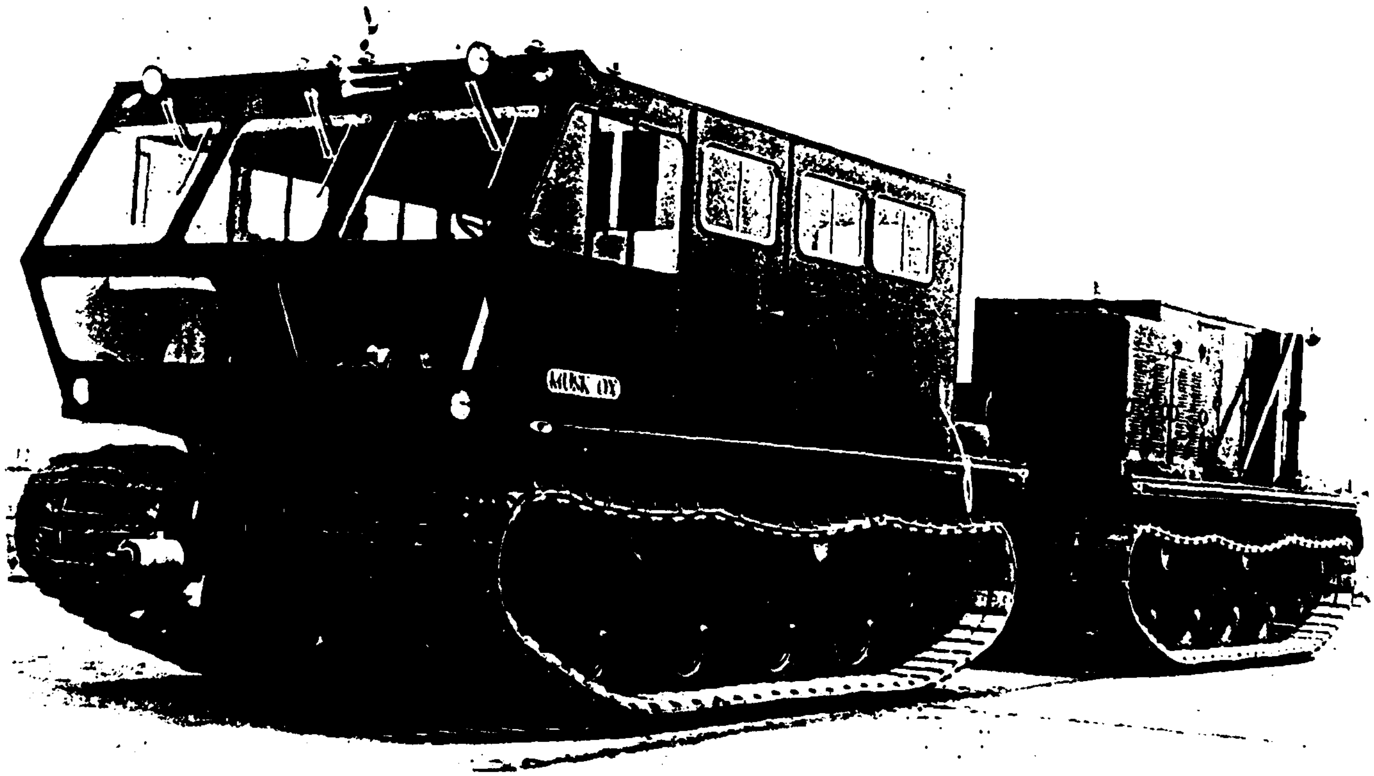

Figure 4. M11 Off-road Dynamometer.

TABLE 2. INSTRUMENTATION USED FOR VARIOUS PERFORMANCE MEASUREMENTS

Type of Measurement	Capacity	Typical Instrumentation
Drawbar pull	0 to 600 kN (0 to 135,000 lb)	Resistance strain gauged mobile dynamometer drawbar or load cell calibrated to indicate drawbar pull on a digital readout
Resistance to towing	0 to 44 kN (0 to 10,000 lb)	
Component temperatures	-73° to 1093°C (-100° to 2000°F)	Copper constantan & chromel-alumel thermocouples with either indicating or recording pyrometer potentiometer
Pressures	0 to 10,000 lb/in^2 0 to 75 in. Hg, absolute 0 to 60 in. H_2O	Bourdon tube-type gauges, manometers, and strain-gauged transducers
Engine and other rotating shaft speeds	0 to 10,000 rpm	Shaft encoders, magnetic and photo sensors, tachometer generators, and associated readout devices
Vehicle road speed	0 to 160 km/hr (0 to 100 mph)	Trailing fifth wheel or non-contact speed indicator with remote direct reading indicator or with recording capability; radar is also used
Stopping distance	Complete coverage	Trailing fifth wheel with remote direct reading indicator
Fuel flow	20 to 1500 lb/hr	Flowmeter with remote indicator or calibrated burette
Rotating shaft torque or component strain	Complete coverage	Strain gauges bonded directly to component; indicating or recording capabilities
Load distribution	0 to 90,000 kg (0 to 200,000 lb) total weight - 0 to 9,000 kg (0 to 20,000 lb) each wheel	Platform scale; portable loadometers
Ride and handling	Complete coverage	Rate gyro, displacement gyro, accelerometers, displacement sensors, strain gauges, and ride quality pads
Suspension travel	Complete coverage	Potentiometer; shaft encoder

2.3 Instrumentation used to Record Vehicle and Component Performance. The vehicle performance recorder (VPR) is an on-board data-acquisition system for automotive endurance and performance testing. The VPR (fig. 5) is a small rugged microcomputer system which samples and records the output of a variety of transducers mounted on the test vehicle. The VPR can be used to record an extensive number of vehicle parameters such as temperature, rotational speeds (engine, drive sprocket, electric motor, etc.), system pressures (air, fuel, hydraulic), suspension deflections, whole body accelerations, vibration levels, and component operational times. By archiving the VPR data, it is possible to compare test conditions for individual items across years, test courses, or proving grounds.

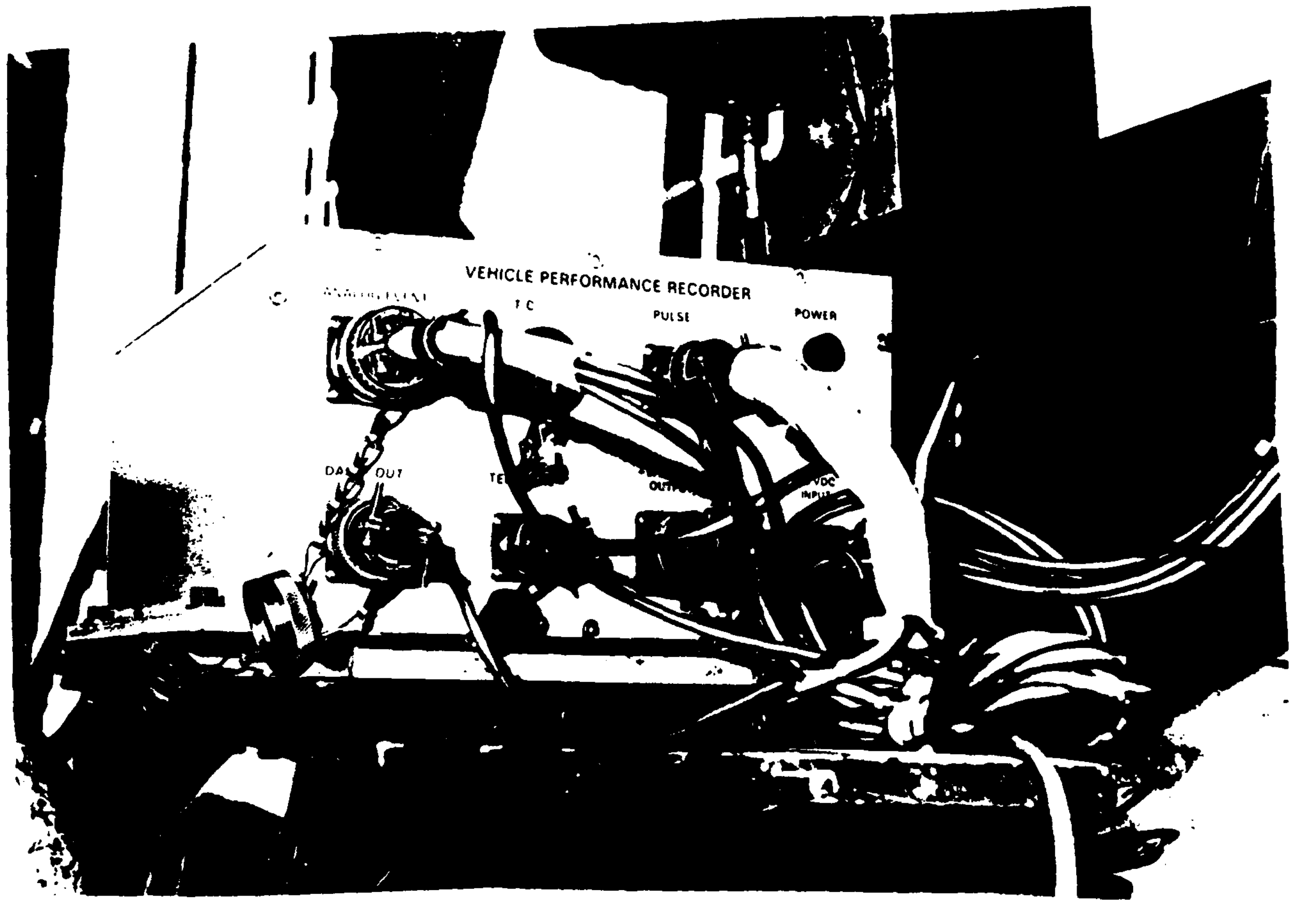

Figure 5. Vehicle performance recorder (VPR).

The VPR performs limited processing of captured data before storing them in memory. This capability allows the VPR to record data continuously over a typical endurance work shift of 10 hours, after which, the data are transferred to a minicomputer/PC for further processing and permanent storage. In addition, this on-board processing allows for real-time monitoring of test conditions, providing feed-back information from the system to the vehicle operator in the form of indicator lights. These lights warn of test item operation outside the testing envelope, thereby assuring consistent testing on a daily and yearly basis.

Data acquired by the VPR are stored and presented in two possible formats: histograms and/or time histories. Histograms record the frequency at which a measurement fell within a certain range during a pre-determined operational period, typically 30 minutes for endurance operation. Currently, histograms of Probability Density Function (PDF) are processed in the VPR and stored on board on a continuous basis. The ordinate of the histogram is the relative probability of the occurrence of the particular signal value on the X axis. NOTE: Additional format possibilities for effective data presentation are being developed.

Time histories consist of on-board data processing by the VPR which permits a readout of mean, minimum, and maximum values of a digitally sampled signal over a selected time period (usually 1 minute). The sampling rate is pre-selected on the basis of knowledge of the frequency content of interest in the data.

The sample rates and operational times before data transfer are inter-dependent due to the limited memory size of the VPR. Higher sample rates reduce the maximum recording time of the VPR before data transfer; conversely, lower sample rates allow extended recording capabilities. Although the VPR is typically configured to record data over a 10-hour operational period, it can be adapted to acquire data at high sample rates (e.g., 100 samples/sec or greater), recording each data point over periods of approximately 40 minutes or less, or to acquire data at low sample rates (e.g., 1 sample/min) for several days or weeks.

3. EQUIPMENT FOR MEASURING SHOCK AND VIBRATION CHARACTERISTICS.

a. Shock and vibration data are collected while operating test vehicles over various test courses using a pulse-code-modulation (PCM) telemetry system. (A block diagram is presented in fig. 6.) The system has signal-conditioning capability for strain gauge, piezoresistive and piezoelectric accelerometers. The strain gauge and piezoresistive signal-conditioning package provides bridge excitation, amplification, and low-pass filtering, while the piezoelectric signal-conditioning package contains a charge amplifier and low-pass filter for each channel. The filter cut-off requirements for these signal conditioners are established by means of plug-in resistor assemblies and are set for each channel. The output of each channel of each signal-conditioning device is connected to a PCM encoder which digitizes each channel in sequence using a 10-bit successive approximation analog-to-digital converter.

b. The digital data stream is then encoded into a nonreturn to zero-level (NRZ-L) code for transmission via a radio telemetry link. The system is capable of handling as many as 128 channels of data; however, a practical upper limit for vibration tests is approximately 60 channels due to a transmission limitation of 100,000 words per second (total rate) and the requirement for a reasonable frequency response of 400 to 500 Hz from each channel. The encoder, signal conditioning and transmitter just described are mounted in the test vehicle, generally in the right front seat of wheeled vehicles or on the turret or other exterior flat surface on tracked vehicles.

c. The transmitted digital data stream is received at a remote data-handling station. A bit synchronizer is used to recover the serial PCM pulse train from data-link noise and perturbations. The "clean" pulse train is then recorded on a PCM tape recorder to preserve the actual transmitted data stream. Voice annotation and International Range Instrumentation Group (IRIG-B) time code are simultaneously recorded on the tape. For on-site data verification and reformatting of the data, a PCM decommutator is used to transform the NRZ-L serial data stream to a 16-bit parallel binary output. The data are then passed through a data merger, where time code is added in a digital form, then through a digital computer and onto a disc storage device. A typical data run lasts approximately 30 seconds during which time 3,000,000 words of data are recorded. Each word represents an acceleration at a particular location at an instant in time. The disc is presently configured to store as many as eight runs. When the disc is full, the data are written to digital magnetic tape, and the disc is then overwritten with the next series of runs.

d. Because of the speed with which the data are acquired, data analysis is not performed during the data-acquisition process. After the test data for a particular run are stored on the disc, two forms of "quick-look" processing are available to validate the data. The primary form of processing is a time-domain amplitude distribution of each channel in the data stream. During this analysis, the rms, +peak, -peak, +99% and -99% are calculated for each channel and are printed in tabular form. (Data are less than or greater than these values 99% of the time.) The secondary form consists of time histories of selected channels in scaled engineering units which are plotted on a graphics terminal.

e. While conducting a test, it is desirable to look at the waveform of at least some portion of the data in real time. A PCM word selector is used to convert selected portions of the data from the digital format to an analog signal. The word selector, connected to the output of the decommutator, selects any words in the data stream (as many as 32) in any sequence and performs an 8-bit digital-to-analog conversion. A low-pass filter is used to smooth the resulting analog signal, and the signals are displayed on a panel of oscilloscopes (as many as 14).

f. Before each day's testing, and whenever a configuration change is made in the instrumentation system, an electrical calibration is performed on each channel. After the calibration data are recorded, a linear least-squares-curve fit is performed to determine the appropriate scale factors (slopes) and offsets (intercepts) for each channel and to determine system linearity. All the scale factors and offsets are stored in a file and are used to scale the data which are always stored in integer form.

4. STEADY STATE NOISE INSTRUMENTATION.

a. Measure steady state noise levels inside and around the exterior of vehicles with microphones, sound level meters, and recording equipment which meet specifications described in TOP 1-2-608[6] and MIL-STD-1474[7]. Evaluate noise level data recorded on magnetic disk amd magnetic tape by using digital frequency analyzers which provide 1/12 octave, 1/3 octave, and 1/1 standard octave band analyses. Steady state noise level instrumentation employed at USACSTA is listed in Table 3.

b. Guidance for measuring and analyzing steady state noise levels is provided in TOP 1-2-608 and MIL-STD-1474B.

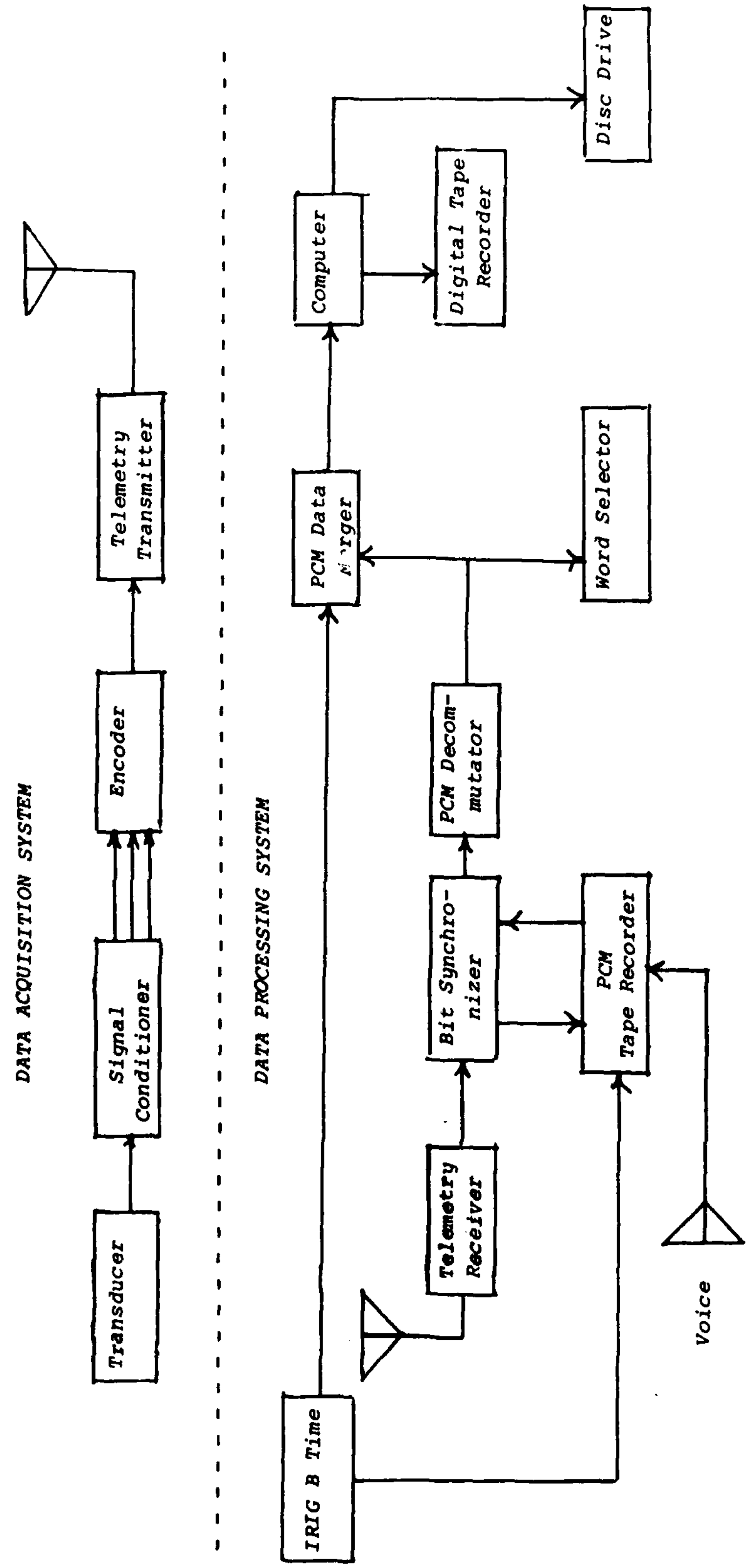

Figure 6. Block diagram of PCM data acquisition and processing system.

TABLE 3. CAPABILITIES OF SOUND PRESSURE MEASURING EQUIPMENT

Equipment	Function and Range
Condenser Microphone	Sensor; random incidence response (±3 dB) 3 Hz to 22 kHz; pressure response (±2 dB) 4 Hz to 20 kHz.
Condenser Microphone	Sensor; pressure response (±2 dB) 4 Hz to 70 kHz.
Condenser Microphone	Sensor; random incidence response (±3 dB) 5 Hz to 100 kHz; pressure response (±2 dB) 6.5 Hz to 140 kHz.
FM tape recorder	Storage and reproduction of microphone signals; DC to 40 kHz.
FM tape recorder	Storage and reproduction of microphone signals; DC to 80 kHz.
Frequency analyzer	Analyzer; provides 1/1 and 1/3 octave band analysis in the frequency range from 20 Hz to 20 kHz.
Frequency analyzer	Analyzer; provides analysis of sound and vibration signals in selectible fractional octaves from 1/1 octave down to 1/24 octave; digital filtering with real-time signal channel operation to 22.4 kHz in 1/1 to 1/3 octave mode.

5. DATA-REDUCTION EQUIPMENT.

a. Shock and vibration data are analyzed using the computer-based system shown in Figure 6. In addition to determining the time-domain amplitude distribution and generating time-history plots as described in paragraph 3, numerous other analyses can be performed with data. These various analyses are made using specialized software programs resident in the system. Such analyses require the data to be transformed from the time domain to the frequency domain using the fast Fourier transform which generates power spectral densities (PSDs) for the data channels.

b. It is not unusual for a vibration test to consist of 50 to 60 channels of data and 40 test runs. Computing PSDs in this quantity can be an extremely time-consuming process. For this reason, the computations contained in the program PSDFL are performed using an array processor. The array processor is a high-speed peripheral device particularly well suited for performing the large numbers of reiterative multiplications and additions required in digital signal processing. The parallel structure of the device allows the "overhead" of array indexing, loop counting and data fetching from memory to be performed simultaneously with arithmetic operations on the data, thus allowing much faster execution than on a typical general-purpose computer where these operations occur consecutively. By making use of the array processor, the program PSDFL can analyze 50 channels of data, which includes computing PSDs, standard deviations and peaks over 26 linear averages (block size of 1024) and storing all information in a file (150 separate spectra) in approximately 10 minutes.

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APPENDIX A
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